Chapter 7
Station Service System

7-1. Power Supply

a. General. A complete station service supply and distribution system should be provided to furnish power for station, dam auxiliaries, lighting, and other adjacent features of the project. The loss of a station service source, either through switching operations or due to protective relay action, should not leave the plant without service power. The station service system should have a minimum of two full-capacity, redundant power sources.

b. Plant "black start" capability.

(1) General. "Black start" capability is desirable at hydro plants since the plants can assist in re-establishing generation for the power system in an emergency. "Black start" capability is defined as the ability of the plant, without an external source of power, to maintain itself internally, start generating units, and bring them up to speed-no-load conditions, close the generator breakers, energize transformers and transmission lines, perform line charging as required, and maintain units while the remainder of the grid is re-established. The plant must then resynchronize to the grid.

(2) Power system problems.

(a) There are a number of circumstances that can lead to collapse of all or parts of a bulk power distribution system. Regardless of the circumstances, the triggering event generally leads to regional and subregional mismatch of loads and generation and "islanding" (i.e., plants providing generation to isolated pockets of load). Separation of generation resources from remote loads and "islanding" can cause voltage or frequency excursions that may result in the loss of other generation resources, particularly steam generation, which is more sensitive to frequency excursions than hydroelectric turbine generators. Steam generation is also harder to return to service than hydro generation, so the burden of beginning system restoration is more likely to fall on hydro resources.

(b) When a transmission line is removed from service by protective relay action, the power it was carrying will either seek another transmission line route to its load, or be interrupted. If its power is shifted to other transmission lines, those lines can become overloaded and also be removed from service by protective relays. System failures are more likely to happen during heavy load periods, when failures cascade because of stress on the system. If the hydro units are running at or near full load when the plant is separated from the system, they will experience load rejections.

(c) Units subjected to a load rejection are designed to go to speed-no-load until their operating mode is changed by control action. Sometimes, however, they shut down completely, and if station service is being supplied by a unit that shuts down, that source will be lost. Units can't be started, or kept on line, without governor oil pressure, and governor oil pressure can't be maintained without a source of station service power for the governor oil pumps.

(d) Assumptions made concerning plant conditions when the transmission grid collapses, thus initiating the need for a "black start," will define the equipment requirements and operating parameters which the station service design must meet. At least one emergency power source from an automatic start-engine-driven generator should be provided for operating governor oil pumps and re-establishing generation after losing normal station service power.

c. For large power plants.

(1) Two station service transformers with buses and switching arranged so that they can be supplied from either the main generators or the transmission system should be provided, with each transformer capable of supplying the total station load. A unit that will be operated in a base load mode should be selected to supply a station service transformer, if possible. Station service source selection switching that will allow supply from either a main unit or the power system should be provided. The switching should be done by interlocked breakers to prevent inadvertent parallel operation of alternate sources. If a main unit is switched on as a source, then the supply should not depend on that unit being connected to the power system. If the power system is switched on as the source, then the supply should not depend on any units being connected to the power system.

(2) To meet Federal Energy Regulatory Commission (FERC) requirements, all reservoir projects should be equipped with an engine-driven generator for emergency standby service with sufficient capacity to operate the spillway gate motors and essential auxiliaries in the dam. The unit is usually installed in or near the dam rather than in the powerhouse. It may also be used to provide emergency service to the powerhouse, although the use of long

supply cables from the dam to the powerhouse could be a disadvantage.

(3) For a large power plant, a second automatic start emergency power source may be required in the powerhouse. Besides diesel engine-generators, small combustion turbines are an option, although they are more complex and expensive than diesel engine-generator sets.

(4) Any emergency source should have automatic start control. The source should be started whenever station service power is lost. The emergency source control should also provide for manual start from the plant control point. It is also important to provide local control at the emergency source for non-emergency starts to test and exercise the emergency source. A load shedding scheme may be required for any emergency source, if the source capacity is limited.

d. For small, one-unit power plants. One station service transformer supplied from the transmission system should be provided for a normal station service bus, and an emergency station service bus should be supplied from an engine-driven generator. The emergency source should have sufficient capacity to operate the spillway gate motors and minimum essential auxiliaries in the dam and powerhouse such as unwatering pumps, governor oil pumps, and any essential preferred AC loads.

e. Station service distribution system.

(1) In many plants, feeders to the load centers can be designed for 480-V operation. In a large plant, where large loads or long feeder lengths are involved, use of 13.8-*kV* or 4.16-*kV* distribution circuits will be satisfactory when economically justified. Duplicate feeders (one feeder from each station service supply bus) should be provided to important load centers. Appropriate controls and interlocking should be incorporated in the design to ensure that critical load sources are not supplied from the same bus. Feeder interlock arrangements, and source transfer, should be made at the feeder source and not at the distribution centers.

(2) The distribution system control should be thoroughly evaluated to ensure that all foreseeable contingencies are covered. The load centers should be located at accessible points for convenience of plant operation and accessibility for servicing equipment. Allowance should be made for the possibility of additional future loads.

(3) All of the auxiliary equipment for a main unit is usually fed from a motor control center reserved for that unit. Feeders should be sized based on maximum expected load, with proper allowance made for voltage drop, motor starting inrush, and to withstand short-circuit currents. Feeders that terminate in exposed locations subject to lightning should be equipped with surge arresters outside of the building.

(4) Three-phase, 480-V station service systems using an ungrounded-delta phase arrangement have the lowest first cost. Such systems will tolerate, and allow detection of, single accidental grounds without interrupting service to loads. Three-phase, grounded-wye arrangements find widespread use in the industrial sector and with some regulatory authorities because of perceived benefits of safety, reliability, and lower maintenance costs over a 480-V delta system. Industrial plants also have a higher percentage of lighting loads in the total plant load. Installation costs for providing service to large concentrations of high-intensity lighting systems are lower with 480/277-V wye systems. Delta systems are still preferred in hydro stations because of the cleaner environment, good service record, and skilled electricians available to maintain the system.

f. Station service switchgear.

(1) Metal-clad switchgear with SF_6 or vacuum circuit breakers should be supplied for station service system voltage above 4.16 *kV*. Metal-enclosed switchgear with 600-V drawout air circuit breakers should be used on 480-V station service systems. The switchgear should be located near the station service transformers.

(2) The station service switchgear should have a sectionalized bus, with one section for each normal station service source. Switching to connect emergency source power to one of the buses, or selectively, to either bus should be provided. If the emergency source is only connected to one bus, then the reliability of the station service source is compromised since the bus supplied from the emergency source could be out of service when an emergency occurred. It is preferable that the emergency source be capable of supplying either bus, with the breakers interlocked to prevent parallel operation of the buses from the emergency source.

(3) Each supply and bus tie breaker should be electrically operated for remote operation from the control room in attended stations. As a minimum, bus voltage indication for each bus section should be provided at the remote point where remote plant operation is provided. Transfer between the two normal sources should be automatic. Transfer to the emergency power sources should

also be automatic when both normal power sources fail. Feeder switching is performed manually except for specific applications.

(4) In large station service systems with a double bus arrangement, source/bus tie breakers should be located at each end of the switchgear compartment. The source/bus tie breakers should not be located in adjacent compartments because a catastrophic failure of one breaker could destroy or damage adjacent breakers leading to complete loss of station service to the plant. In large plants where there is sufficient space, it is even safer to provide a separate, parallel cubicle lineup for each station service bus for more complete physical isolation. Even with this arrangement, feeder and tie breakers should not be located in adjacent compartments.

(5) For 480-V station service systems, a delta-connected, ungrounded system is recommended for the following reasons:

(a) Nature of the loads. The load in a hydroelectric power plant is made up predominantly of motor loads. In a commercial or light industrial facility, where the load is predominantly lighting, the installation of a 480/277 V, wye-connected system is more economical due to the use of higher voltages and smaller conductor sizes. These economies are not realized when the load is predominantly motor loads. For high bay lighting systems, certain installation economies may be realized through the use of 480/277-V wye-connected subsystems, as described in Chapter 12.

(b) Physical circuit layout. Wye-connected systems allow the ability to quickly identify and locate a faulted circuit in a widely dispersed area. Although hydroelectric power plants are widely dispersed, the 480-V system is concentrated in specific geographic locales within the plant, allowing rapid location of a faulted circuit, aided by the ground detection system described in paragraph 7-2.

7-2. Relays

An overlapping protected zone should be provided around circuit breakers. The protective system should operate to remove the minimum possible amount of equipment from service. Overcurrent relays on the supply and bus tie breakers should be set so feeder breakers will trip on a feeder fault without tripping the source breakers. Ground overcurrent relays should be provided for wye-connected station service systems. Ground detection by a voltage relay connected in the broken delta corner of three potential transformers should be provided for ungrounded or delta-connected systems (ANSI C37.96). Bus differential relays should be provided for station service systems of 4.16 *kV* and higher voltage. The adjustable tripping device built into the feeder breaker is usually adequate for feeder protection on station service systems using 480-V low-voltage switchgear.

7-3. Control and Metering Equipment

Indicating instruments and control should be provided on the station service switchgear for local control. A voltmeter, an ammeter, a wattmeter, and a watthour meter are usually sufficient. A station service annunciator should be provided on the switchgear for a large station service system. Contact-making devices should be provided with the watthour meters for remote indication of station service energy use. Additional auxiliary cabinets may be required for mounting breaker control, position indication, protective relays, and indicating instruments. For large plants, physical separation of control and relay cubicles should be considered so control and relaying equipment will not be damaged or rendered inoperable by the catastrophic failure of a breaker housed in the same or adjacent cubicle.

7-4. Load/Distribution Centers

Protective and control devices for station auxiliary equipment should be grouped and mounted in distribution centers or, preferably, motor control centers. The motor starters, circuit beakers, control switches, transfer switches, etc., should all be located in motor control centers.

7-5. Estimated Station Service Load

a. General.

(1) The maximum demand that is expected on the station service system is the basis for developing station service transformer ratings. The expected demand may be determined from a total of the feeder loads with an appropriate diversity factor, or by listing all connected loads and corresponding demand loads in *kVA*. A diversity factor smaller than 0.75 should not be used. During high activity periods or plant emergencies, higher than normal station service loads can be expected and if a small diversity factor has been used, the system may not have adequate capacity to handle its loads.

(2) Demand factors used for developing station service equipment capacities can vary widely due to the type of plant (high head stand-alone power plant versus

low head power plant integrated with a dam structure and navigation lock). Development of demand factors for unit auxiliaries should account for the type of auxiliaries in the plant based on trends observed at similar plants. For instance, the governor oil pump demand for a Kaplan turbine will be greater than that for the governor oil pump demand for a Francis turbine of the same output rating because of the additional hydraulic capacity needed to operate the Kaplan turbine blades. If the plant is base loaded, governor oil pumps will not cycle as often as governor oil pumps in a similar plant used for automatic generation control or peaking service.

(3) Station service systems should be designed to anticipate load growth. Anticipated growth will depend on a number of factors including size of the plant, location, and whether the plant will become an administrative center. A one- or two-unit isolated plant not suitable for addition of more units would not be expected to experience a dramatic increase in demand for station service power. For such a plant, a contingency for load growth of 20 percent would be adequate. Conversely, some large multi-purpose plants have experienced 100-percent increases in the connected *kVA* loads on the station service system over original design requirements.

(4) Capacity deficits in existing station service systems have not been caused by the designer's inability to predict unit auxiliary requirements, but by unforeseeable demands to provide service for off-site facilities added to multipurpose projects. Examples of this have been the development of extensive maintenance and warehouse facilities outside the power plant, or electrical requirements resulting from environmental protection issues such as fish bypass equipment. The station service design should have provisions for unanticipated load growth for multipurpose projects with navigation locks and fish ladders. For such projects, a minimum growth factor contingency adder of 50 percent could be justified.

b. Auxiliary demand. Demand varies greatly with different auxiliaries, and the selection of demand factors requires recognition of the way various power plant equipments will be operated. One method illustrated in Table 7-1 assumes 1 *hp* as the equivalent of 1 *kVA* and on lights and heaters uses the *kW* rating as the *kVA* equivalent. The accuracy of the method is within the accuracy of the assumptions of demand and diversity. The values of demand and diversity factors correlate with trends observed in recent years on station service loads.

Table 7-1
Estimated Station Service Load and Recommended Transformer Capacity

Function		Connected Load kVA	Demand kVA
Unit Auxiliaries for 8 Units			
Governor Oil Pump			
Pump #1 Bus #1	8 @ 100 *hp*	800.00	400.00
Pump #2 Bus #2	8 @ 100 *hp*	800.00	
Pump #3 Bus #1	4 @ 25 *hp*	100.00	50.00
Pump #4 Bus #2	4 @ 25 *hp*	100.00	
Turbine Bearing Oil Pump	8 @ 1 *hp*	8.00	8.00
Head Cover Pump			
Pump #1 Bus #1	8 @ 2 *hp*	16.00	16.00
Pump #2 Bus #2	8 @ 2 *hp*	16.00	
High Bay Lights			
Bus #1	7 @ 13 *kW*	91.00	91.00
Bus #2	7 @ 13 *kW*	91.00	
Generator Housing Heater	8 @ 18 *kW*	144.00*	
Transformer Cooling Water Pumps			
Bus #1	2 @ 50 *hp*	100.00	100.00
Bus #2	2 @ 50 *hp*	100.00	
Transformer Oil Pump			
Bus #1	12 @ 2 *hp*	24.00	24.00
Bus #2	12 @ 2 *hp*	24.00	
ACB Air Compressor			
Bus #1	1 @ 5 *hp*	5.00	5.00
Bus #2	1 @ 10 *hp*	10.00	10.00

(Continued)

Table 7-1 (Concluded)

Function		Connected Load *kVA*	Demand *kVA*
High Pressure Thrust			
Bearing Oil Pump	8 @ 10 *hp*	80.00	
Governor Air Compressor	2 @ 15 *hp*	30.00	
General Auxiliaries			
Supply to Dam		696	205
Fire Pump		25	25
HVAC-Heat Pump		380	36
Transit Oil Processor		20	20
Transit Oil Pump		10	10
Battery Charger No. 1		10	10
Battery Charger No. 2		10	0**
Elevator		25	25
Power Outlets		--	25
Draft Tube Crane		50	0
Duplex Sump Pump		15	7.5
Powerhouse Crane No. 1		100	0
Air Compressor No. 1		20	20
Air Compressor No. 2		20	0**
Filter Paper Oven		2	2
Lubricating Oil Purifier		14	14
Lubricating Oil Pump		5	0
Water Heater - 20 gal.		2	2
Water Heater - 100 gal.		5	2
Switchyard			
Cable Tunnel Ventilating Fan		5	5
Power Outlets		-	5
Lighting		37.5	30
Air Compressors		6	2
Machine Shop			
Largest Machine			15
Total less heating		3852.5	1164.50
Total demand with diversity factor of 75 percent			873.4 kVA
Estimated total heating load			1055.0 kVA
Estimated total demand load with heating			1928.4 kVA
Recommended size of each station service transformer			1500.0 kVA

* Not on when generator running.
** Standby